Review Article

A survey on technical approaches in fall detection system

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Abstract

The fall events have become a common health problem among elderly people. The accidental falls are a serious issue. If it is unnoticed, then it becomes fatal. The concept of automatic fall detection technique is monitoring the daily activities of a person when they encounter a fall and then send an alert to the particular person's caretaker in order to get an immediate assistance. A survey was done on several techniques used for automatic detection of fall events. The techniques widely used are categorized as follows: (1) acoustic and ambience sensor based, (2) wearable sensor based, and (3) computer vision based. The advantages and disadvantages of these techniques are analyzed critically in this article.

KEY WORDS: Fall detection; acoustic sensor; accelerometer; computer vision; activities of daily living

Introduction

In 2050, one about five people in each group will be older than 60 years. If this aged person encounters a fall often, it will cause severe problems and lead to accidental death.[1] One-third of a half of the population in an aged care home face these life-threatening events on a yearly basis.[2] So, one of the national patient safety goals (NPSGs) in China is to reduce patient injury from fall events.[3] Therefore, the automatic fall detections would facilitate them by reducing the arrival time of health-care provider and mortality rate.[4] Falls cause hip fracture for 90% of elderly people who are older than 70 years.[5] Falls may also cause social, psychological, and medical consequences. The conventional method to ensure the safety of elderly people is the supervision of their daily activities through hired nurse. It provides the burden on caregivers, because of a need to accompany them all the time. The caregivers can also take care of only a few patients at a time, which finally increase the personnel required in home care. Moreover, it is impossible to supervise everyone completely, and hiring more personnel will increase the cost.

This is why a new-automated fall detection system has been equipped to reduce the caregiver dependency using the latest technologies. Reliable and cost-effective options must be considered when providing security for the elderly people. Modern technologies provide a better standard of living for aged people with a reduced cost of health-care facilities. In order to make safety measures, automatic monitoring system for fall detection is to be developed for helping aged people by making calls to caregivers when the patient falls unconscious.

The methods to detect a fall automatically can be widely classified into three types such as (1) acoustic and ambient sensors-based method, (2) wearable sensors-based method, and (3) computer vision-based method.

In acoustic-based fall detection method, detection of fall events is based on the vibration of falling subject's frequency component. In wearable sensors-based method, kinematic sensors such as a gyroscope and an accelerometer are used to identify the fall during daily life activities. The computer vision-based method is a real-time monitoring of the subject through video, and the postures of the subject is determined by an algorithm. It provides higher accuracy when compared with the other methods. This approach minimizes the efforts of caregivers and ensures proper care. Inspite of these advantages, the state-of-the-art method for detection of fall is in the early stages of development. It requires a great deal of research to overcome the drawbacks in the conventional method.

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Moreover, an approach needs to be developed to monitor many people concurrently and to prevent the elder people suffer from heavy injury by forecasting a fall event before it occurs.

A survey of the advantages and disadvantages of the existing methods in fall detection system is done in this article. The intention of this work is to provide the point of reference for research in future by identifying the potential areas in the automatic fall detection domain. The survey on the existing methods in fall detection techniques is discussed in detail further.

Acoustic and Ambience Sensors-Based Method

These class of systems include microphones and infrared sensors. Acoustic techniques are similar to the computer vision techniques. The architecture of this system is inexpensive and simple. It consists of an ambience or acoustic sensor and a personal computer. The gathered data obtained from the sensors are sent to a personal computer for analysis. The analysis is made based on certain conditions and thresholds to detect a fall event.

Related Work

Sixsmith and Johnson[6] have designed an automatic system called smart inactivity monitor using array-based detectors (SIMBAD). It consists of an array of infrared sensors. The thermal target can be tracked and located by infrared sensors while within its field of view. Two different characteristics are considered to observe the behavior of the target. First, the system analyzes the motion of the target to detect dynamic characteristics of fall activity and then monitors the inactivity of the target. A prototype of this system is carried out with field trials and the SIMBAD gives the effective and functional enhancement, when compared with community alarms and monitoring systems, in a significant way. The drawback of this system is the limited range of infrared sensors. Thus, it is confined to limited applications, especially, it is suitable for indoor monitoring and not for the outdoor monitoring.

Alwan et al.[7] have developed a passive system to the occupant, which is floor vibration-based fall detector system. By using spring and mass arrangement, piezoelectric sensors can be coupled to the surface of the floor. This system differentiates the patterns of vibration of targeted object's fall from nontargeted object's fall and a fall event from other daily activities. Anthropomorphic test dummies were used for laboratory tests. It results in 100% recognition rate with a minimum number of false alarms. The drawback of the above-mentioned two methods is the limitation of detection range. In addition, all sorts of floor materials cannot be detected by vibration sensors.

Popescu et al.[8] proposed an array-based acoustic sensors to detect a fall. The fall is recognized by the loudness of the object. Two microphones are placed apart by 4 ft and mounted on the *z*-axis. First, the removal of noise is done. Second, the signal energy from both the sensors are considered as the source for decision-making. This system provides 70% detection rate, but 100% detection rate could be achieved through adjustments in the system. It is also confined to indoor applications. Figure 1 depicts an architecture of acoustic sensor-based method.

Liu et al.[9] have designed a Doppler radar sensor-based fall detection system. This system acquired data by web camera and range control radar (RCR). The Fourier transform and support vector machine (SVM) classifier are detected events and differentiate fall events from nonfall events, respectively. An RCR can be mounted on either the ceiling or wall. The wall-mounted RCR is less sensitive than the ceiling-mounted RCR.

Ariani et al.[10] detected a fall using wireless dual technology sensors, which include pressure mats and infrared sensors. One or more person's fall can be identified by path finding algorithm. Two undirected graphs are modeled to monitor the activities of each one in a group of people. One undirected graph describes sensors in a system, and another one describes physical contiguousness profiles. It yields 89% accuracy, 77% specificity, and 100% sensitivity.

Perspectives Discussion

Unlike computer vision techniques, the privacy issues can be eliminated by the usage of ambient sensors. It is inexpensive and simple. In addition, these types of sensors are more sensitive to noise. Thus, it is not suitable for living environments. Monitoring more number of people is also possible with this approach, but it requires an immense amount of domain research. It is well suited for indoor applications.

Wearable Sensors-Based Method

Wearable sensors-based method is more preferable than acoustic-based method. In some detection systems, either an accelerometer or a gyroscope is used, and some used both the sensors to detect falls during daily activities. The microcontroller or personal computer processed the data from the sensors. These wearable sensors are able to operate independently. Therefore, the activities of elderly people are monitored constantly.

Related Work

Bourke et al.[11] simulated fall detection through the triaxial accelerometer. It is placed in the trunk and on thigh, which

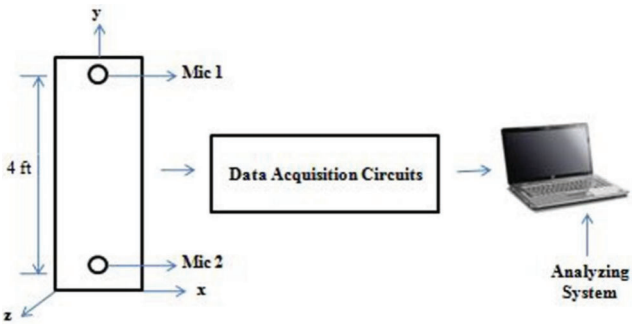

Figure 1: Architecture of acoustic sensor-based method.

monitors the activities of daily living (ADL). The performance of a system is found out with the support of 10 aged people. It yields 100% sensitivity with a number of false alarms. From the analysis of this system, it was foud that tri-axial accelerometer that is placed on the trunk detects fall events efficiently rather than placed on the thigh.

Tong et al.[12] proposed a fast response system with the help of buttons, which avoid false alarms. The specific directions and a rate of change in velocity are detected by a gyroscope and an accelerometer, respectively. These sensors are placed on the back or chest of the person. The threshold value is predefined in the algorithm. According to the value, the values from an accelerometer and a gyroscope are equated. If the values exceed limits, then the button is pressed to indicate a fall. The alarm is considered as false when it has been unpressed for 20 s. The advantage of this system is owing to the negligible amount of false alarm.

Li et al.[13] proposed a system that measures the angular velocity and linear acceleration by placing a gyroscope and a tri-axial accelerometer on the thigh and chest. A microcontroller is used to speedup the processing of data from the sensors. The different types of postures including sitting, lying, bending, and standing are recognized by this embedded system. The recognition is better when acquiring information from both angular velocity and linear acceleration when compared with information about orientation.

Nguyen et al.[14] placed a device in a particular person's waist. The system consists of multichannel electroencephalogram (EEG) circuit, an accelerometer and a code division multiple assess (CDMA) modem. The thresholding algorithm is used. The heart rate of a particular person is measured by EEG circuit, which has 3 channels. Every activity of a person is analyzed by creating a database using remote server through CDMA modem. The response time is higher than the local processing system.

Zheng et al.[15] uses an accelerometer, global system for mobile communications (GSM) modem with global positioning system (GPS) one module. The detection of fall is performed along with tracking the location of a person. The sensor is placed on the waist of a person. The alert is sent to the caretaker when the elderly people encounter fall activity. With the help of some people, tests were carried out 325 times. The system provided false alarm in 81 tests and worked well in 255 tests.

Dinh et al.[16] developed a system consisting of tri-axis accelerometer, heart beat sensor, and ZigBee transceivers. The data are transmitted wirelessly through ZigBee protocol. The device is placed on the chest. The network comprises a personal computer, which collects and stores the monitoring information. The battery can be charged when it lowers by alerting a device through ZigBee connection. The sensors get turned off automatically while charging a battery. The device was tested using five algorithms. When the accelerometer is used, the device provides 92% accuracy. By adding up gyroscope to a system, the accuracy increased to 97%.

Huang et al.[17] proposed a system consisting of ZigBee tag with accelerometer. The ZigBee tag includes an antenna and CC2431 Microcontroller, which is made by combining two different elements: wireless ZigBee location engine and 8051 kernel.

Wang et al.[18] computed an algorithm for the detection of fall. It can differentiate seven sorts of ADL and eight sorts of falling patterns. The location of a falling person is identified through the ZigBee location engine and indicated to the caregiver by call. Figure 2 describes an architecture of wearable sensors-based method.

Perspectives Discussion

The literature survey describes that the above-mentioned system is cost-effective and robust to noise. It is suitable for both indoor and outdoor applications. It has numerous advantages when compared with the acoustic and ambience sensor-based system. This system does not require any infrastructure. Therefore, there is no need to set a communication network unlike the existing methods. A low-battery life and an obtrusive way of monitoring the people are its disadvantages. The weight should be considered, because it creates a burden on the wearer.

Computer Vision Method

Computer vision-based systems abstract information from raw images for processing or analyzing. The data can be any one among such as video sequences and perspective views from multicam. Computer vision is the science and technology of

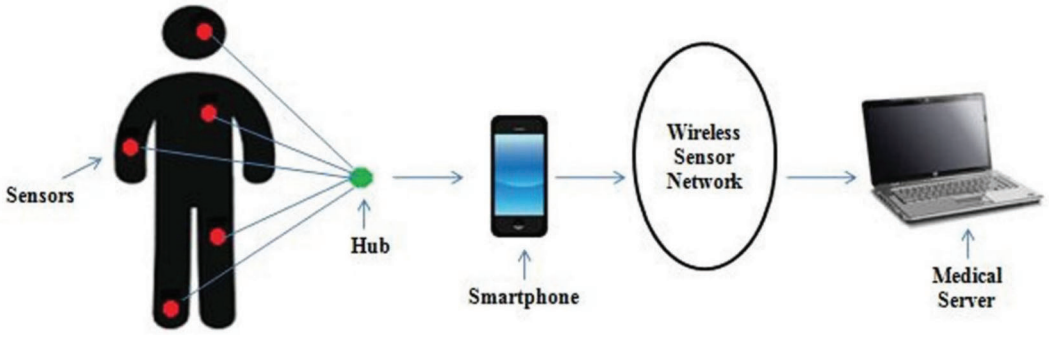

Figure 2: Architecture of wearable sensors-based method.

machines that have the ability to see. The term computer vision is defined as: "The process whereby a machine, usually a digital computer, automatically processes an image and reports what is in the image." The computer vision technique consists of three parts such as the measurement of features, pattern classification based on those features, and pattern recognition.

Related Work

Cucchiara et al.[19] proposed a fall detection system with a mounted camera and online workstation. First step in this vision technique is background detection. The second step is subtracting the background pixels to identify foreground pixels of each frame. To achieve a better segmentation, processing of ghost and shadow pixels are carried out. The posture estimation uses projection histograms. When a person lay on for a longer period of time, then the system considered this activity as a fall and raise the alarm. The shortcomings are that the system cannot distinguish crouching and standing. The system results in 90% accuracy.

Miaou et al.[20] detection system has a computer server and an omnidirectional camera. The advantage of using omnidirectional camera is that it can capture a 360° view in a single shot. It overcomes the blind spots issue. The image segmentations are done to remove the noise of the current frame. Finally, a rectangular bounding box is created around the subject. The falls are identified by calculating aspect ratio, that is, the height to the width of the rectangular bounding box. This system gives 78% sensitivity when the information about the user is not provided. If the information such as height of the user is given, then the sensitivity becomes 90%.

The multiview fall detection system by Thome et al.[21] has two cameras. These cameras work using fuzzy logic technique. After all the preprocessing steps, the images obtained from the each camera are processed independently with an algorithm, and finally, extracted features from all the images are merged in order to make a decision. Layered hidden Markov model (LHMM) is used to identify the fall events from the fall-like events. Multiview requirements are sufficed by two cameras. The experimental result shows 97.08% accuracy.

Nasution and Emmanuel[22] have developed a system using a single camera and a personal computer. After the completion of segmentation process, the extracted features use both vertical and horizontal projection histograms. The foreground bounding box is analyzed, and then the speed of falling is considered to detect a fall. The fall detection rate is 90%. The drawbacks are blind spots, which are owing to the presene of a single camera, and the occlusion problem because of a dynamic background.

Huang et al.[23] used distributed cameras and a computer server. A dynamic background model is used for segmentation. Two different parameters are considered to detect a fall. Then, the bounding box enclosing the subject is used to analyze the postures of a person. The aspect ratio of bounded box is computed, and it is taken as "α" and the root mean square (RMS) value is taken as "β." Both the values are increase or decrease according to the person falls. The 52% accuracy rate is achieved when only α is considered. Accuracy of 78% is achieved when considering both the α and β.

Foroughi et al [24] used a system, which is based on variations of human postures. A silhouette is obtained from a color image by the image segmentation and a morphological process. The ellipse is fitted around the silhouette image. The temporal head movements are taken into account to make decisions. The multiclass SVM classifier is used to classify the postures. The experimentation resulted in 88.08% reliability rate. The diagrammatic representation of computer vision-based method is shown in Figure 3.

Perspectives Discussion

Multiple people can be monitored through computer vision-based techniques. The major problems of the wearable sensors-based techniques are that it makes the older person to wear the sensors often, and the usage of buttons is also ineffective when a person goes senseless. Moreover, batteries are required for these types of devices. Therefore, it must be recharged regularly. These problems are overcome by the computer vision-based technique. It provides a higher accuracy when compared with the other methods. It also sends an alert message to the caregiver when the elder people encounter fall using GSM technology. Limits in range are the disadvantage of the computer vision-based technique, because the camera used to monitor the people is fixed; therefore, there is a need to fix more number of cameras in the living environment. An infrastructure is required to make communications, and the multiple cameras are connected to a single server, which maintain databases. Thus, they predominantly increase the setup cost.

Figure 3: Diagrammatic representation of computer vision method.

Conclusion

This article gives a survey and the advantages and disadvantages of three methodologies used for fall detection system.The kinematic sensors are cost-effective but cause discomfort to the wearer. The other two methods have several disadvantages such as range limits, more sensitive to noise from a living environment, nonportable, and increasing maintenance cost owing to the installation of servers in a smart home. The wearable sensors-based method is desirable, which monitors the people constantly, whether in indoor or in outdoor. This system is suitable for those who live independently. The computer vision approach can monitor more number of people at the same time in an unobtrusive way. This technique is well suited for oldage homes. To reduce the implementation cost of computer vision, the GSM technology can be employed instead of servers to alert a caregiver.

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